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APPLICATION NUMBER: *10/183,768*
FILING DATE: *June 26, 2002*
RELATED PCT APPLICATION NUMBER: *PCT/US03/20197*

By Authority of the
COMMISSIONER OF PATENTS AND TRADEMARKS

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06-28-02

UTILITY PATENT APPLICATION TRANSMITTAL
(for Noncontinuing, Nonprovisional
Applications under 37 C.F.R. §1.53(b))

Attorney Docket No. 11843/22

Box PATENT APPLICATION
Commissioner for Patents
Washington, D.C. 20231

Sir:

Transmitted herewith for filing under 37 C.F.R. §1.53(b) is the nonprovisional, noncontinuation patent application for:

Title: **Electron Impact Ion Source**

First Named Inventor or
Application Identifier: **Horsky**

CERTIFICATE OF MAILING BY "EXPRESS MAIL"

"Express Mail" Mailing Label Number
EL547618829US

Date of Deposit: June 26, 2002

I hereby certify that this paper or fee is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" Service under 37 CFR §1.10 on the date indicated above and is addressed to the Commissioner for Patents, Washington, D.C. 20231.

Molly M. Michaels
(Typed or printed name of person mailing)

Molly M. Michaels
(Signature of person mailing)

1. **Utility Patent Application:**

   14 pages of the specification *(including claims)* are enclosed.

   5 sheet(s) of drawings are enclosed. ( ) Formal (X) Informal

2. **Declaration and Power of Attorney:**

   ( ) An executed Oath or Declaration and Power of Attorney naming the actual inventors is enclosed.

   (X) The names of persons believed to be the actual inventors are set forth in the enclosed ***unexecuted*** Oath or Declaration and Power of Attorney (§1.41(a) and §1.53(b)).

3. **Assignment:**

   ( ) Assignment(s) of the invention to ______________________ and cover sheet are enclosed.

   ( ) A check in the amount of $__________ to cover the fee for recording the assignment(s) is enclosed. *($40.00 per assignment.)*

4. ( ) A 37 C.F.R. §3.73(b) Statement is enclosed *(where an Assignee seeks to take action in a matter before the Patent Office).*

5. ( ) An Information Disclosure Statement is enclosed.

( ) A Form PTO-1449 is enclosed.

( ) References (copies) listed on the Form PTO-1449 are enclosed.

6. (X) A Return Receipt Postcard is enclosed (MPEP §503).

7. ( ) Priority of application number_____ filed on _____ in _____ is claimed under 35 U.S.C. §119.

( ) A certified copy of the priority document is enclosed.

8. ( ) A MicroFiche Computer Program (Appendix) is enclosed.

9. ( ) A Nucleotide and/or Amino Acid Sequence Submission is enclosed.

10. ( ) A Computer Readable Copy is enclosed.

11. ( ) A Paper Copy *(Identical to Computer Copy)* is enclosed.

12. (X) Small Entity Status is claimed under 37 C.F.R. §1.27.

13. **The filing fee is calculated below:**

CLAIMS AS FILED – INCLUDING PRELIMINARY AMENDMENT (IF ANY)						
			SMALL ENTITY		*LARGE ENTITY*	
	NO. FILED	NO. EXTRA	RATE	FEE	RATE	FEE
BASIC FEE				$370.00		$740.00
TOTAL (No. of claims – 20=)	10	--	X $9.00	--	X $18.00	
INDEP. (No. of claims – 3=)	1	--	X $42.00	--	X $84.00	
Assumed no multiple dependent claims – □ First Presentation of Multiple Dependent Claim			+ $135.00	$370.00	+ $270.00	
Filing Fee =			$370.00			

14. **Method of Payment of Fees**

(X) Enclosed is a firm check in the amount of: **$370.00**

( ) Charge $_____to Deposit Account No. 50-1214.

( ) The payment of the Filing Fee is to be deferred until the Declaration is filed. Do not charge our Deposit Account.

15. ( ) A separate written request under 37 C.F.R. §1.136(a)(3), which is a general authorization to treat any concurrent or future reply requiring a petition for an extension of time under 37 C.F.R. §1.136(a) for its timely submission as incorporating a petition for an extension of time for the appropriate length of time, is enclosed.

16. (X) The Commissioner is hereby authorized to charge any additional fees which may be required in this application under 37 C.F.R. §§1.16-1.17 during its entire pendency, or credit any overpayment, to Deposit Account No. 50-1214. Should no proper payment be enclosed herewith, as by a check being in the wrong amount, unsigned, post-dated, otherwise improper or informal or even entirely missing, the Commissioner is authorized to charge the unpaid amount to Deposit Account No. 50-1214. This sheet is filed in triplicate.

17. ( ) Also enclosed:

Please address all future communications to:

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Attention: Patent Administrator
525 West Monroe Street, Suite 1600
Chicago, Illinois 60661-3693

Respectfully Submitted,

June 26, 2002
(Date)

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Attorney Docket No. 11843/22

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Molly M. Michaels
(Typed or printed name of person mailing)

(Signature of person mailing)

Electron Impact Ion Source

Cross-Reference to Related Applications

[0001] The following patent applications, herein incorporated by reference, are related to the present application: PCT Application Serial Number PCT/US00/33786, filed December 13, 2000, entitled "Ion Implantation Ion Source, System and Method", inventor Thomas N. Horsky; PCT Application No. PCT/US01/18822, filed June 12, 2001, entitled "Ion Implantation with High Brightness, Low Emittance Ion Source, Acceleration-Decleration", inventor Thomas N. Horsky; PCT Application Serial No. PCT/US02/03258, filed February 5, 2002, entitled, "Ion Source for Ion Implantation", inventor Thomas N. Horsky and U.S. Application No. 09/736,097, filed December 13, 2000, entitled "Electron Beam Ion Source with Integral Low Temperature Vaporizer" inventor Thomas N. Horsky.

Background of the Invention

1. Field of the Invention

[0002] The present invention relates to an ion source and more particularly to an ion electron impact ion source.

2. Description of the Prior Art

[0003] Ion implantation has been a key technology in semiconductor device manufacturing for more than twenty years, and is currently used to fabricate the p-n junctions in transistors, particularly in CMOS devices such as memory and logic chips. By creating positively-charged ions containing various dopant elements, such as, ^{75}As, ^{11}B, ^{115}In, ^{31}P, or ^{121}Sb, required for fabricating the transistors in, for example, silicon substrates, known ion implanters can selectively control both the energy (hence implantation depth) and ion current (hence dose) of ions introduced into transistor structures. Ion implanters have traditionally used ion sources which generate ribbon beams of up to about 50mm in length. These beams are transported to the substrate at a predetermined uniform dose by electromagnetic scanning of the beam across the substrate, mechanical scanning of the substrate across the beam, or both.

[0004] So-called medium current implanters typically incorporate a serial (one wafer at a time) process chamber, which offers high tilt capability (e.g., up to 60 degrees from substrate normal). The ion beam is typically electromagnetically scanned across the wafer, in an orthogonal direction to ensure dose uniformity. In order to meet implant dose uniformity and repeatability requirements which typically allow only a few per cent variance in these quantities, the ion beam should have excellent angular and spatial uniformity (angular uniformity of beam on wafer of <2deg, for example). The production of beams possessing these characteristics imposes severe constraints on the beam transport optics of the implanter, and the commonplace use of large-emittance plasma-based ion sources often results in increased beam diameter and beam angular divergence, causing beam loss during transport due to vignetting of the beam by the various apertures present within the beam line of the implanter. Currently, the generation of high current (>1 mA) ion beams at low (<5 keV) energy is problematic in serial implanters, such that wafer throughput is unacceptably low for certain low-energy implants (for example, in the creation of source and drain structures in leading-edge CMOS processes). Similar transport problems also exist for batch implanters (processing many wafers mounted on a spinning disk) at the low beam energies of <5 keV per ion.

[0005] While it is possible to design beam transport optics which are nearly aberration-free, the ion beam characteristics (spatial extent, spatial uniformity, angular divergence and angular uniformity) are nonetheless largely determined by the emittance properties of the ion source itself (i.e., the beam properties at ion extraction which determine the extent to which the

implanter optics can focus and control the beam as emitted from the ion source). Arc-discharge plasma sources currently in use have poor emittance, and therefore severely limit the ability of ion implanters to produce well-focused, collimated, and controllable ion beams. Thus, there is a need for an ion source for use in a semiconductor manufacturing which provides a well-focused, collimated and controllable ion beam.

Summary of the Invention

[0006] Briefly, the present invention relates to an ion source configured for integration into both existing ion implanters used in semiconductor manufacturing and emerging ion implantation platforms, and is also suitable for use in ion dosing systems used in the processing of flat panel displays. The ion source in accordance with the present invention includes the following features, all of which depart from the prior art to produce a well-focused, collimated and controllable ion beam:

- Ionizing electron beams generated external to the ionization chamber, thereby extending the emitter lifetime.
- 90 degree magnetic deflection of electron beams such that no line-of-sight exists between the emitter and the process gas load, and the emitter is protected from bombardment by energetic charged particles.
- Two opposed electron beams which can be operated simultaneously or separately.
- Use of a deceleration lens to adjust the ionization energy of the electron beam, substantially without affecting electron beam generation and deflection.

Description of the Drawings

[0007] These and other advantages of the present invention will be readily understood with reference to the following specification and attached drawing wherein:

[0008] FIG. 1 is a perspective view of an ion source in accordance with the present invention, shown in cutaway to expose internal components.

[0009] FIG. 2 is a side view of a portion of the ion source shown in FIG. 1, shown in cutaway with the electron beams and magnetic fields shown superimposed thereupon.

[0010] FIG. 3 is a perspective view of a portion of the ion source shown in cutaway which illustrates the magnetic field and electron beam sources in accordance with the present invention.

[0011] FIG. 4 is a simplified top view of the electron beam forming region of the ion source in accordance with the present invention.

[0012] FIG. 5 is a graphical illustration of the ionization cross section σ as a function of electron energy T of ammonia (NH_3).

[0013] FIG. 6 is a block diagram of a temperature control system which can be used in conjunction with the present invention.

Detailed Description

[0014] The ion source which forms a part of the ion implantation system in accordance with the present invention is an electron impact ionization source. FIG. 1 is a cross-sectional schematic diagram of the ion source in accordance with the present invention which illustrates the construction and the functionality of the components which make up the ion source 10. The cross section is cut along a plane which contains the direction of propagation of the ion beam, separating the ion source in two halves. The ion source 10 includes a vaporizer 28 and a beam forming region 12 joined together by at a mounting flange 36. The ion source 10 is made to interface to an evacuated vacuum chamber of an ion implanter or other process tool by way of the mounting flange 36. Thus, the portion of the ion source 10 to the right of the flange 36 in FIG. 1 is at high vacuum (pressure $< 1\times10^{-4}$ Torr). Gaseous material is introduced into an ionization chamber 44 where the gas molecules are ionized by electron impact from one or more electron beams 70a and 70b which enter the ionization chamber 44 through a pair of opposing electron beam entrance apertures 71a and 71b, respectively. With such a configuration, ions are created adjacent to an ion extraction aperture 81 in ion an extraction aperture plate 80. These ions are extracted and formed into an energetic ion beam by an extraction electrode (not shown) located in front of an ion extraction aperture plate 80.

[0015] Various vaporizers 28 are suitable for use with the present invention. An exemplary vaporizer 28 is illustrated in FIG. 1. The vaporizer 28 is exemplary and may be formed from a vaporizer body 30 and a crucible 31 for carrying a solid source feed material 29, for example, decaborane, $B_{10}H_{14}$. Resistive heaters may be embedded into the vaporizer body 30. Water cooling channels 26 and convective gas cooling channels 27 may be configured to be in intimate contact with the vaporizer body 30 and used to provide a uniform operating temperature above room temperature to the crucible 31. Thermal conduction between the crucible 31 and the temperature-controlled vaporizer body 30 may be provided by way of a pressurized gas, introduced by a gas feed 41 into a crucible-vaporizer body interface 34, while the temperature of

the vaporizer body 31 is monitored by a thermocouple. Vaporized decaborane $B_{10}H_{14}$ or other vaporized material 50 collects in a crucible ballast volume 51 and passes through a vaporizer exit bore 39, through a pair of isolation valves 100 and 110, and through a vapor conduit 32, contained in a source block 35, and enters the ionization chamber 44 through a vapor entrance aperture 33.

[0016] The isolation valves 100, 110, mounting flange 36, and the source block 35 may also be temperature controlled to a temperature near or above the vaporizer temperature to prevent condensation of the vapor.

[0017] The ion source gas delivery system may include two conduits that feed the ionization chamber 44 from two separate sources. The first source may be a small diameter, low-conductance path which feeds gaseous material from a pressurized gas source, such as a gas cylinder (not shown). The second source may be from a high-conductance path from a low-temperature vaporizer, which vaporizes solid material. Regardless of the source, the gas delivery system maintains a gas pressure of, for example, a few millitorr, in the ionization chamber 44. The vaporizer 28 maintains tight temperature control of its surfaces which are in contact with the solid material, in order to maintain a stable flow of gas into the ionization chamber, and hence a stable pressure within said chamber.

[0018] Prior to servicing the vaporizer 28, the isolation valve 110 can be closed to keep the ion source and the ion implanter under vacuum. The isolation valve 100 can also be closed to maintain containment of the vapor 50 within the crucible 31. The vaporizer 28 can then be transported safely to a chemical hood, where the crucible 31 can be recharged or cleaned. Prior to opening the valve 100, a vent valve 111, which may be welded into the body of valve 100, can be opened to bring the crucible volume to atmospheric pressure. Once service is complete, the valve 100 may be again closed and the vaporizer 28 may be mounted onto the ion source 10 by attaching the valve 100 to the valve 110, and the vent valve 111 is then connected to a roughing line to evacuate the crucible 31 and the dead volume between the valve 100 and the valve 110. The isolation valve 110 can then be opened if desired, without compromising the vacuum environment of the ion source and ion implanter.

[0019] A vaporizer assembly 30a is formed by a heated and cooled vaporizer body 30 and a removable crucible 34. Access to the crucible 31 is possible by removing an end plate (not

shown) on the back of the vaporizer 28. Once the crucible 31 is removed from the vaporizer 28, it can be recharged by removing its cover 34b that is elastomerically sealed to the end of the crucible 31 and raising a grate 34a which isolates the solid 29. After recharge, the crucible 31 is inserted in the vaporizer body 30 and a vacuum seal is made to the exit bore 39 at the front of the vaporizer body 30, to isolate the crucible ballast volume 51 from thermal transfer gas present within crucible-vaporizer body interface 34. The bore 39 is used as the exit for the vaporized gas. The mechanical fit between the crucible 31 and the vaporizer body 30 is close, in order to achieve temperature uniformity of the crucible 31. Any gap between the crucible 31 and the vaporizer body 30 may be filled with a gas to facilitate thermal transfer between the two surfaces. The thermal transfer gas enters said gap through an end plate fitting 28a, and may be at or near atmospheric pressure.

[0020] Temperature control may be performed using, for example, a proportional-integral differential (PID) closed-loop control of resistive elements that may be embedded in the vaporizer body 30. FIG. 6 shows a block diagram of a preferred embodiment in which three temperature zones are defined: zone 1 for vaporizer body 30, zone 2 for isolation valves 100 and 110, and zone 3 for the source block 35. Each zone may have a dedicated controller; for example, an Omron E5CK Digital Controller. In the simplest case, heating elements alone are used to actively control temperature above room ambient, for example, between 18 C to 300 C or higher. Thus, resistive cartridge-type heaters can be embedded into the vaporizer body 30 (heater 1) the and the source block 35 (heater 3), while the valves 100, 110 can be wrapped with silicone strip heaters (heater 2) in which the resistive elements are wire or foil strips. Three thermocouples labeled TC1, TC2, and TC3 in FIG. 6 can be embedded into each of the three components 30, 35, 100 (110) and continuously read by each of the three dedicated temperature controllers. The temperature controllers 1, 2, and 3 are user-programmed with a temperature setpoint SP1, SP2, and SP3, respectively. In one embodiment, the temperature setpoints are such that SP3>SP2>SP1. For example, in the case where the vaporizer temperature is desired to be at 30C, SP2 might be 50C and SP3 70C. The controllers typically operate such that when the TC readback does not match the setpoint, the controller's comparator initiates cooling or heating as required. For example, in the case where only heating is used to vary temperature, the comparator output is zero unless TC1<SP1. The controllers may contain a look-up table of output power as a nonlinear function of temperature difference SP1-TC1, and feed the

appropriate signals to the controller's heater power supply in order to smoothly regulate temperature to the programmed setpoint value. A typical method of varying heater power is by pulse-width modulation of the power supply. This technique can be used to regulate power between 1% and 100% of full scale. Such PID controllers can typically hold temperature setpoint to within 0.2C.

[0021] The vaporizer body material may be selected to be highly thermally conductive to maintain temperature uniformity. A small thermal leak may be intentionally applied to the vaporizer body 30 to improve control system stability and reduce settling time by using air channels located on the outside surface of the vaporizer body 30. The air channels 27 surround the vaporizer body 30 and are covered by plates (not shown). Air may be ducted to the channels within a manifold system, integrated into a vaporizer end plate (not shown) to provide moderate, continuous convective cooling. The air is fed through the inlet after proceeding past a metering valve used for flow control. The air discharges from the air assembly into house exhaust.

[0022] In addition to air cooling, provisions may also be provided for liquid cooling the vaporizer body 30. For example, a coolant may be ducted through a, for example, 1 meter long, 6 mm diameter bore that travels back and forth throughout the vaporizer body 30. Connections may be made through fittings mounted to the body ports 26. The liquid cooling provides rapid cooling of the vaporizer assembly to provide quick service turnaround when required.

[0023] Gases may be fed into the ionization chamber 44 via a gas conduit 33, for example, from a pressurized gas cylinder. Solid feed materials can be vaporized in the vaporizer 28, and the vapor fed into ionization chamber 44 through the vapor conduit 32, described above. Solid feed material 29, located under the perforated separation barrier 34a, is held at a uniform temperature by temperature control of the vaporizer body 30, as discussed above. Vapor 50 which accumulates in ballast volume 31 feeds through the bore 39 and through the shutoff valves 100 and 110 and, in turn, is fed into the ionization chamber 44 by way of a vapor conduit 32, located in the source block 35. Thus, both gaseous and solid dopant-bearing materials may be ionized by this ion source.

[0024] FIG. 2 is a cross-sectional side view which illustrates the fundamental optical design of a multiple electron-beam ion source configuration in accordance with the present invention. In one embodiment of the invention, a pair of spatially separate electron beams 70a and 70b are

emitted from a pair of spatially separate heated filaments 110a and 110b and execute 90 degree trajectories due to the influence of beam steerers or static magnetic fields B 135a and 135b (in a direction normal to the plane of the paper as indicated) into the ionization chamber 44, passing first through a pair of base plate apertures 106a and 106b and a pair of spaced apart base plates 105a and 105b, and then through a pair of electron entrance apertures 71a and 71b. Electrons passing all the way through the ionization chamber 44 (i.e., through both of the electron entrance apertures 71a and 71b) are bent toward a pair of emitter shields 102a and 102b by the beam steerers, or static magnetic fields 135a and 135b. As the electron beams propagate through the base plate apertures 106a and 106b, they are decelerated prior to entering ionization chamber 44 by the application of a voltage Va to the base plates 105a and 105b (provided by positive-going power supply 115), and voltage Ve to the filaments 135a and 135b (provided by negative-going power supply 116). It is important to maintain electron beam energies significantly higher than typically desired for ionization in the beam-forming and the transport region, i.e., outside of ionization chamber 44. This is due to the space charge effects which severely reduce the beam current and enlarge the electron beam diameter at low energies. Thus, it is desired to maintain the electron beam energies between about 1.5 keV and 5 keV in this region.

[0025] Voltages are all relative to the ionization chamber 44. For example, if Ve = - 0.5 kV and Va = 1.5 kV, the energy of the electron beam is therefore given by e(Va-Ve), where e is the electronic charge (6.02×10^{-19} Coulombs) . Thus, in this example, the electron beam 70a, 70b is formed and deflected at an energy of 2 keV, but upon entering electron entrance aperture 71a, 71b it has an energy of only 0.5 keV.

[0026] The following table gives approximate values of magnetic field B required to bend an electron beam with energy E through 90 degrees.

Table 1

Dependence of Magnetic Field Strength on Electron Energy to Accomplish a 90 Degree Deflection in the Present Invention

Electron Energy E	Magnetic Field B
1500 eV	51 G
2000 eV	59 G
2500 eV	66 G

[0027] Other elements shown in FIG. 2 include an extracted ion beam 120, a source electrostatic shield 101, and a pair of emitter shields 102a and 102b. These emitter shields 102a and 102b serve two purposes: to provide shielding from electromagnetic fields, and to provide shielding from stray electron or ion beams. For example, the emitter shields 102a and 102b shield the electron beams 70a and 70b from fields associated with the potential difference between base plates 105a and 105b and the source shield 101, and also acts as a dump for stray electron beams from the opposing electron emitter. The source shield 101 shields the ion beam 120 from fields generated by the potential difference between base plates 105a and 105b and the ionization chamber 44, and also acts to absorb stray electrons and ions which would otherwise impact the ion source elements. For this reason, both of the emitter shields 102a and 102b, as well as the source shield 101, are constructed of refractory metal, such as molybdenum or graphite. Alternatively, more complete shielding of the ion beam 120 from the magnetic fields B 135a and 135b may be accomplished by constructing the source shield 101 of a ferromagnetic substance, such as magnetic stainless steel.

[0028] FIG. 3 is a cutaway view illustrating the mechanical detail and which shows explicitly how the contents of FIG. 2 are incorporated into the ion source of FIG. 1. Electrons are thermionically emitted from one or more of the filaments 110a and 110b and accelerated to a pair of corresponding anodes 140a and 140b forming the electron beams 70a and 70b. Such a configuration offers several benefits. First, the filaments 110a and 110b can be operated separately or together. Second, since the electron beams 70a, 70b are generated external to the ionization chamber, the emitter life is extended relative to known configurations, since the emitter is in the low-pressure environment of the implanter vacuum housing in which the ion source resides, and since the emitter is also effectively protected from ion bombardment.

[0029] Magnetic flux from a pair of permanent magnets 130a and 130b and a pair of magnetic pole assemblies 125a and 125b is used to form beam steerers used to establish uniform magnetic fields across the air gap between the ends of the magnetic pole assemblies 125a, 125b, wherein the electron beam 70a, 70b propagates. The magnetic fields 135a and 135b and the electron beam energies of electron beams 70a and 70b are matched such that electron beams 70a and 70b are deflected 90 degrees, and pass into the ionization chamber 44 as shown. By deflecting the

electron beams 70a and 70b, for example, through 90 degrees, no line of sight exists between the emitters and the ionization chamber 44 which contains the ions, thus preventing bombardment of the emitters by energetic charged particles.

[0030] Since Va is positive relative to the ionization chamber 44, the electron beams 70 are decelerated as they pass through the gap defined by base plate apertures 106a and 106b and the electron entrance apertures 71a and 71b. Thus, the combination of the base plate aperture 106a and electron entrance aperture 71a, and baseplate aperture 106b and electron entrance aperture 71b, and the gaps between them, each forms an electrostatic lens, in this case, a decelerating lens. The use of a decelerating lens allows the ionization energy of the electron beam to be adjusted without substantially affecting the electron beam generation and deflection.

[0031] The gap may be established by one or more ceramic spacers 132a and 132b, which support each base plate 105a and 105b and act as a stand off from the source block 35, which is at ionization chamber potential. The ceramic spacers 132a and 132b provide both electrical isolation and mechanical support. Note that for clarity, the emitter shields 102 and the source shield 101 are not shown in FIG. 3.

[0032] Since the electron entrance apertures 106a and 106b can limit transmission of the electron beams, the baseplates 105a and 105b can intercept a portion of the energetic electron beams 10a, 70b. The baseplates 105a, 105b must therefore be either actively cooled, or passively cooled. Active cooling may be accomplished by passing liquid coolant, such as water, through the baseplates. Alternatively, passive cooling may be accomplished by allowing the baseplates to reach a temperature whereby they cool through radiation to their surroundings. This steady-state temperature depends on the intercepted beam power, the surface area and emissivity of the baseplates, and the temperatures of surrounding components. Allowing the baseplates 105a, 105b to operate at elevated temperature, for example at 200C, may be advantageous when running condensable gases which can form contaminating and particle-forming films on cold surfaces.

[0033] FIG. 4 shows a simplified top view of the electron beam-forming region of the source. The filament 110b is at potential Ve, for example, -0.5 keV with respect to the ionization chamber 44, and the anode 140b, the magnetic pole assembly 125b, the base plate 105b, and the emitter shield 102b are all at anode potential Va, for example, 1.5 keV. Thus, the electron beam

energy is 2 keV. The electron beam 70b is deflected by the magnetic field 135b in the air gap between the poles of the magnetic pole assembly 125b, such that the electron beam 70b passes through the base plate aperture 106b. Typical values for the base plate apertures 106a and 106b and the electron entrance apertures 71a and 71b are 1 cm in diameter, respectively.

[0034] FIG. 5 illustrates how ionization probability depends on the electron energy for electron impact ionization. Ammonia (NH_3) is used as an illustration. Probability is expressed as cross section σ, in units of 10^{-16} cm^2. Electron energy (T) is in eV, i.e., electron-volts. Shown are two sets of theoretical curves marked BEB (vertical IP) and BEB (adiabatic IP) calculated from first principles, and two sets of experimental data, from Djuric et al. (1981) and from Rao and Srivastava (1992). FIG. 5 illustrates the fact that certain ranges of electron energies produce more ionization than in other energy ranges. In general, cross sections are highest for electron impact energies between about 50eV and 500eV, peaking at about 100eV. Thus, the energy with which the electron beams enter the ionization chamber 44 is an important parameter which affects the operation of the ion source of the present invention. The features shown in FIG. 2 through FIG. 4 show how the present invention incorporates electron optics which allow for broad control of electron impact ionization energy while operating at nearly constant conditions in the electron beam-forming and deflection regions of the ion source.

[0035] Obviously, many modifications and variations of the present invention are possible in light of the above teachings. Thus, it is to be understood that, within the scope of the appended claims, the invention may be practiced otherwise than as specifically described above.

[0036] What is claimed and desired to be covered by a Letters Patent is as follows:

We Claim:

1. An ion source comprising:

an ionization chamber, said ionization chamber including a vapor entrance aperture for receiving gaseous feed material, an extraction aperture for emitting an ionized beam and one or more electron beams, said one or more electron beams being generally parallel to the plane of said extraction aperture;

one or more electron beam sources, disposed to generate one or more electron beams in a direction generally perpendicular to the plane of said extraction aperture; and

one or more beam steerers for bending said one or more electron beams so that said one or more electron beams travel in a direction generally parallel to the plane of said extraction aperture and are received in said one or more electron entrance apertures.

2. The ion source as recited in claim 1, wherein each of said beam steerers includes a magnetic field source configured to generate a magnetic field in a direction generally perpendicular to said electron beam.

3. The ion source as recited in claim 2, wherein at least one of said one or more electron beam sources is a filament.

4. The ion source as recited in claim 2, further including an anode disposed adjacent each of said electron beam sources.

5. The ion source as recited in claim 4, further including a power supply for maintaining said anode at a fixed voltage potential Va and said electron source at a fixed voltage potential Ve.

6. The ion source as recited in claim 5, wherein $Ve < Va$.

7. The ion source as recited in claim 6, further including a pair of base plates disposed adjacent said ionization chamber, each of said base plates including a base plate aperture aligned with said electron entrance apertures defining a gap between said base plates and said ionization chamber.

8. The ion source as recited in claim 7, where the potential of the ionization chamber is maintained at a predetermined value relative to the anode potential forming an electrostatic lens.

9. The ion source as recited in claim 8, wherein the potential of the ionization chamber is maintained at a value < Va causing the electrostatic lens to act as a decelerating lens.

10. The ion source as recited in claim 1, wherein at least one of said one or more magnetic field sources includes a permanent magnet.

Electron Impact Ion Source

Abstract of the Disclosure

An ion source configured for integration into both existing ion implanters used in semiconductor manufacturing and emerging ion implantation platforms, and is also suitable for use in ion dosing systems used in the processing of flat panel displays. The ion source in accordance with the present invention includes the following features, all of which depart from the prior art to produce a well-focused, collimated and controllable ion beam:

- Ionizing electron beams generated external to the ionization chamber, thereby extending the emitter lifetime.
- 90 degree magnetic deflection of electron beams such that no line-of-sight exists between the emitter and the process gas load, and the emitter is protected from bombardment by energetic charged particles.
- Two opposed electron beams which can be operated simultaneously or separately.
- Use of a deceleration lens to adjust the ionization energy of the electron beam, substantially without affecting electron beam generation and deflection.

DECLARATION FOR PATENT APPLICATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that my residence, post office address and citizenship are as stated below next to my name; I believe that I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled **"Electron Impact Ion Source,"** the specification of which (check one): **(X)** is attached hereto; **( )** was filed on as Application Serial No. _____ and was amended on _____(if applicable); **( )** was filed as PCT International Application No. _____on _____and was amended under Article 19 on _____ (if applicable). I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment(s) referred to above. I acknowledge the duty to disclose to the Patent and Trademark Office all information known to me to be material to patentability as defined in 37 C.F.R. §1.56.

I hereby claim foreign priority benefits under 35 U.S.C. §119 of any foreign application(s) for patent or inventor's certificate or of any PCT international application(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application(s) for patent or inventor's certificate or any PCT international application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application(s) of which priority is claimed:

			Priority Claimed	
			☐	☐
(Application Serial Number)	(Country)	(Month/Day/Year Filed)	Yes	No
			☐	☐
(Application Serial Number)	(Country)	(Month/Day/Year Filed)	Yes	No

I hereby claim the benefit under 35 U.S.C. §119(e) of any United States provisional application(s) listed below:

(Application Serial Number)	(Month/Day/Year Filed)
(Application Serial Number)	(Month/Day/Year Filed)

I hereby claim the benefit under 35 U.S.C. §120 of any United States application(s) or PCT international application(s) designating the United States of America listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior application(s) in the manner provided by the first paragraph of 35 U.S.C. §112, I acknowledge the duty to disclose to the Office all information known to me to be material to patentability as defined in 37 C.F.R. §1.56 which occurred between the filing date of the prior application(s) and the national or PCT International filing date of this application:

(Application Serial Number)	(Month/Day/Year Filed)	(Status-Patented, Pending or Abandoned)
(Application Serial Number)	(Month/Day/Year Filed)	(Status-Patented, Pending or Abandoned)

Declaration and Power-of-Attorney

Attorney Docket No. 11843/22

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. §1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

POWER OF ATTORNEY: I hereby appoint as my attorneys, with full powers of substitution and revocation, to prosecute this application and transact all business in the Patent and Trademark Office connected therewith:

Timothy J. Vezeau	26,348	Scott M. Gettleson	38,158
John S. Paniaguas	31,051	Jane J. Choi	39,980
Richard P. Bauer	31,588	Jill E. Uhl	43,213
Gilberto M. Villacorta	34,038	James A. Gromada	44,727
Corinne M. Poliquen	35,753	Dawn C. Hayes	44,751
David W. Clough	36,107	Michael A. Dorfman	46,669
Martin T. LeFevour	37,378		

Send correspondence to:

FIRM NAME	PHONE NO.	STREET	CITY & STATE	ZIP CODE
Katten Muchin Zavis Rosenman Attn: Patent Administrator	312-902-5200	525 West Monroe Street, Suite 1600	Chicago, Illinois	60661-3693

Declaration and Power-of-Attorney

Attorney Docket No. 11843/22

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State or Country Massachusetts	State or Country
Date ☒	Signature ☒

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Residence Address - Street	Post Office Address - Street
City (Zip)	City (Zip)
State or Country	State or Country
Date ☒	Signature ☒

Full Name of First or Sole Inventor	Citizenship
Residence Address - Street	Post Office Address - Street
City (Zip)	City (Zip)
State or Country	State or Country
Date ☒	Signature ☒

Declaration and Power-of-Attorney

Attorney Docket No. 11843/22

APPLICABLE RULES AND STATUTES

37 CFR 1.56. DUTY OF DISCLOSURE - INFORMATION MATERIAL TO PATENTABILITY (Applicable Portion)

(a) A patent by its very nature is affected with a public interest. The public interest is best served, and the most effective patent examination occurs when, at the time an application is being examined, the Office is aware of and evaluates the teachings of all information material to patentability. Each individual associated with the filing and prosecution of a patent application has a duty of candor and good faith in dealing with the Office, which includes a duty to disclose to the Office all information known to that individual to be material to patentability as defined in this section. The duty to disclose information exists with respect to each pending claim until the claim is canceled or withdrawn from consideration, or the application becomes abandoned. Information material to the patentability of a claim that is canceled or withdrawn from consideration need not be submitted if the information is not material to the patentability of any claim remaining under consideration in the application. There is no duty to submit information which is not material to the patentability of any existing claim. The duty to disclose all information known to be material to patentability is deemed to be satisfied if all information known to be material to patentability of any claim issued in a patent was cited by the Office or submitted to the Office in the manner prescribed by §§ 1.97(b)-(d) and 1.98. However, no patent will be granted on an application in connection with which fraud on the Office was practiced or attempted or the duty of disclosure was violated through bad faith or intentional misconduct. The Office encourages applicants to carefully examine:

(1) prior art cited in search reports of a foreign patent office in a counterpart application, and
(2) the closest information over which individuals associated with the filing or prosecution of a patent application believe any pending claim patentability defines, to make sure that any material information contained therein is disclosed to the Office.

Information relating to the following factual situations enumerated in 35 USC 102 and 103 may be considered material under 37 CFR 1.56(a).

35 U.S.C. 102. CONDITIONS FOR PATENTABILITY: NOVELTY AND LOSS OF RIGHT TO PATENT

A person shall be entitled to a patent unless –
(a) the invention was known or used by others in this country, or patented or described in a printed publication in this or a foreign country, before the invention thereof by the applicant for patent, or
(b) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the date of the application for patent in the United States, or
(c) he has abandoned the invention, or
(d) the invention was first patented or caused to be patented, or was the subject of an inventor's certificate, by the applicant or his legal representatives or assigns in a foreign country prior to the date of the application for patent in this country on an application for patent or inventor's certificate filed more than twelve months before the filing of the application in the United States, or
(e) the invention was described in a patent granted on an application for patent by another filed in the United States before the invention thereof by the applicant for patent, or on an international application by another who has fulfilled the requirements of paragraph (1), (2), and (4) of section 371(c) of this title before the invention thereof by the applicant for patent, or
(f) he did not himself invent the subject matter sought to be patented, or
(g) before the applicant's invention thereof the invention was made in this country by another who had not abandoned, suppressed, or concealed it. In determining priority of invention there shall be considered not only the respective dates of conception and reduction to practice of the invention, but also the reasonable diligence of one who was first to conceive and last to reduce to practice, from a time prior to conception by the other.

35 U.S.C. 103. CONDITIONS FOR PATENTABILITY; NON-OBVIOUS SUBJECT MATTER (Applicable Portion)

A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

Subject matter developed by another person, which qualifies as prior art only under subsection (f) or (g) of section 102 of this title, shall not preclude patentability under this section where the subject matter and the claimed invention were, at the time the invention was made, owned by the same person or subject to an obligation of assignment to the same person.

35 U.S.C. 112. SPECIFICATION (Applicable Portion)

The specification shall contain a written description of the invention, and of the manner and process of making and using it, in such full, clear, concise, and exact terms as to enable any person skilled in the art to which it pertains, or with which it is most nearly connected, to make and use the same, and shall set forth the best mode contemplated by the inventor of carrying out his invention.

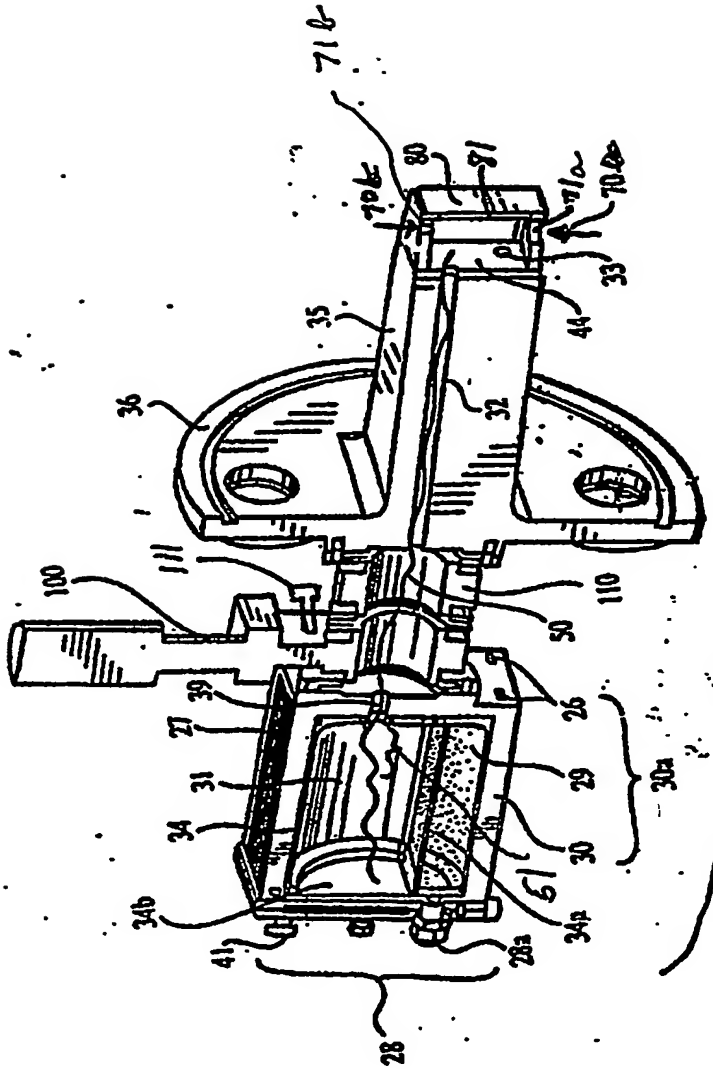
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FIG. 1

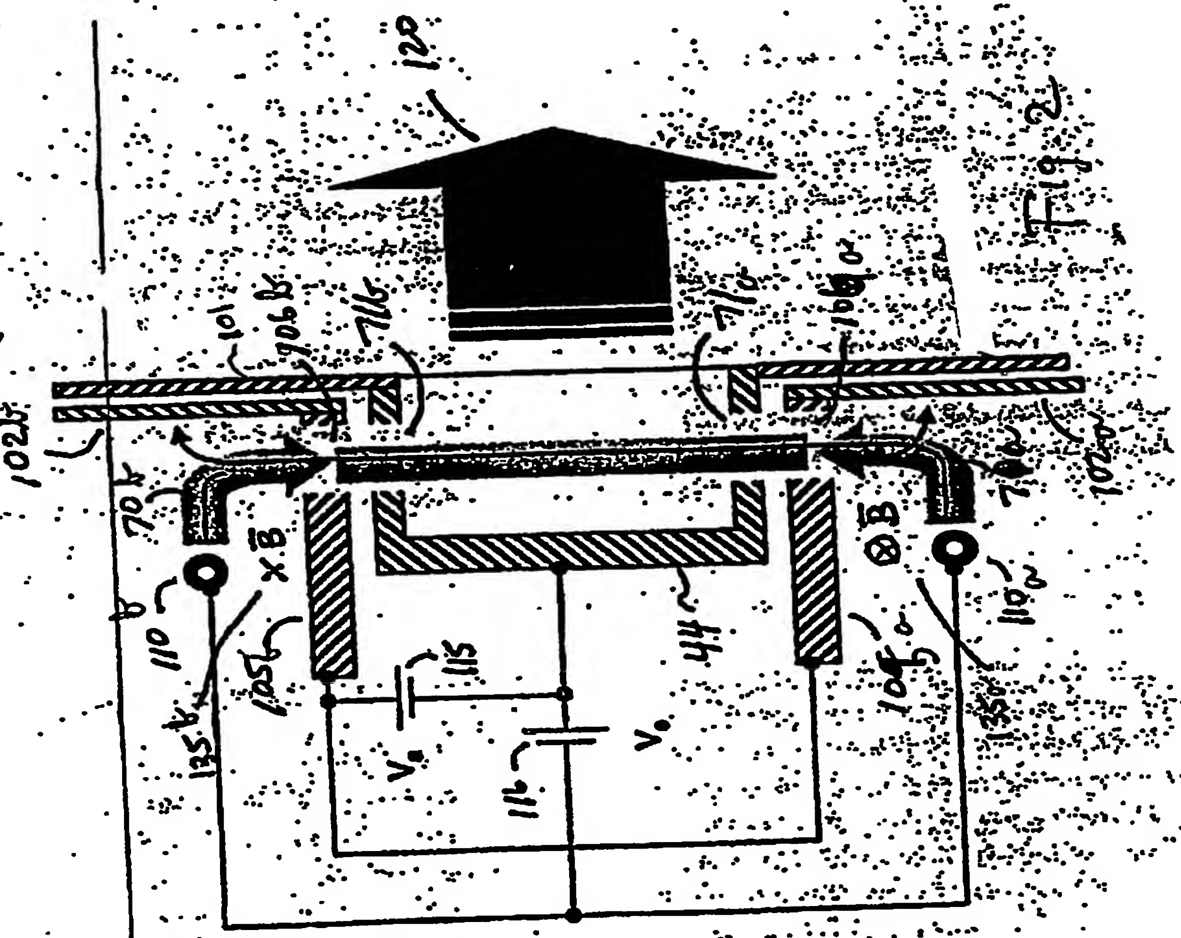
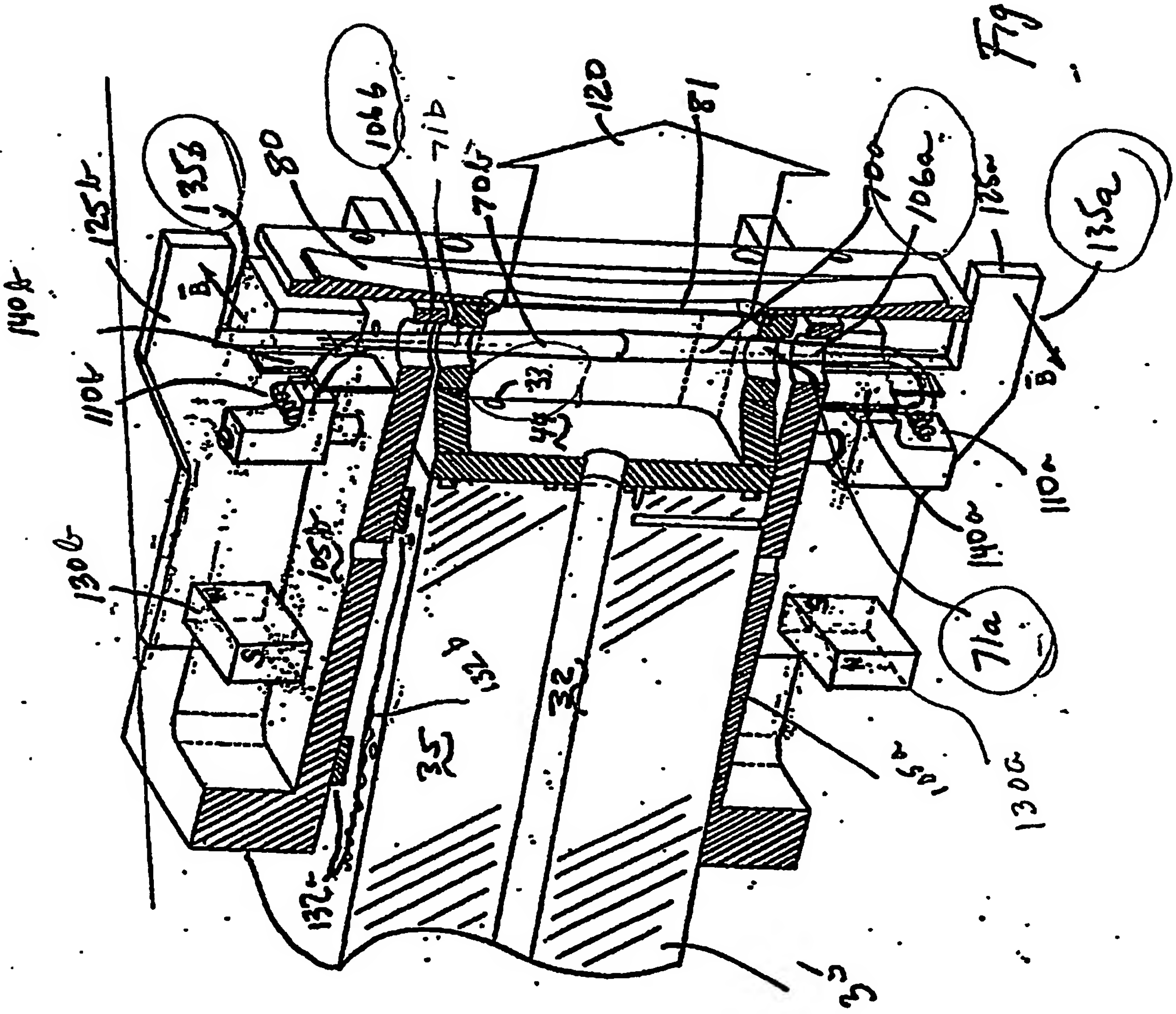


Fig 2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135b
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132
B

Fig. 3

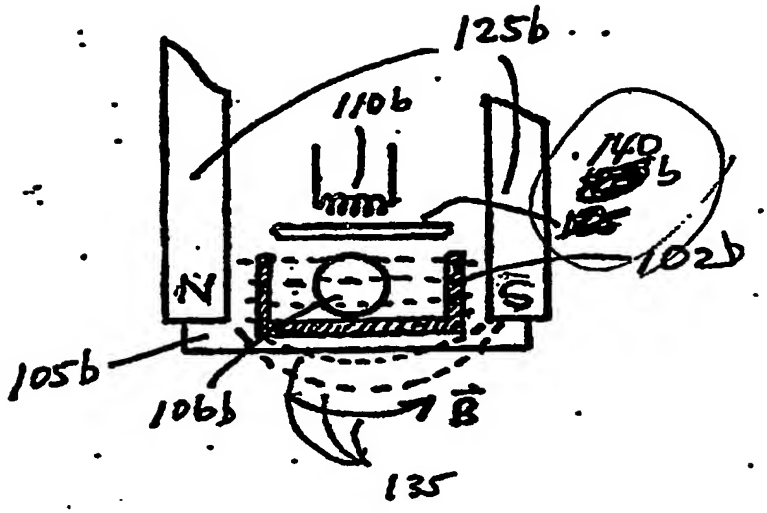
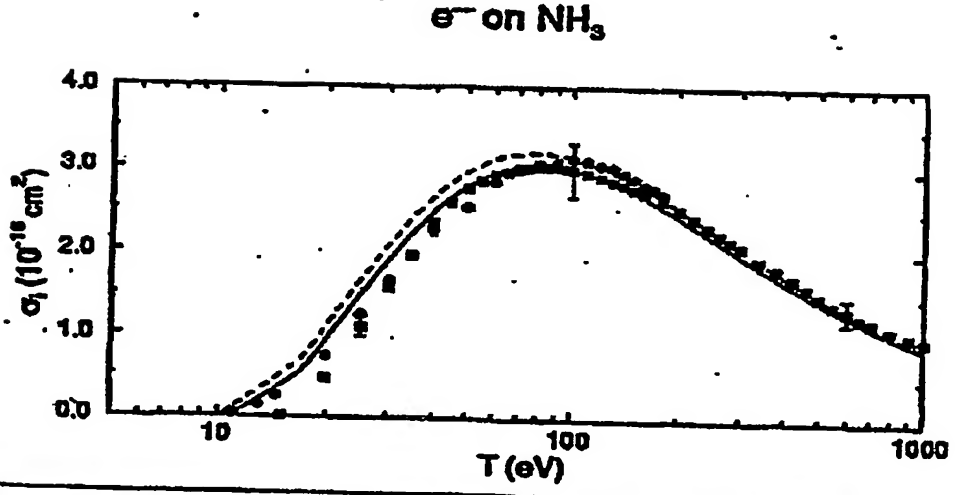


FIG 4



Data set	Source
——	BEB (vertical IP) Y.-K. Kim, W. Hwang, N. M. Weinberger, M. A. Ali and M.E. Rudd, J. Chem. Phys. 106, 1026 (1997).
- - -	BEB (adiabatic IP) W. Hwang, Y.-K. Kim and M.E. Rudd, J. Chem. Phys. 104, 2956 (1996).
●	N. Djuric, D. Belic, M. Kurepa, J. U. Mack, J. Rothleitner and T. D. Märk, Abstracts, 12th Int. Conf. on the Physics of Atomic and Electronic Collisions, ed. by S. Datz (Gatlinburg, 1981), p. 384
■	M. V. V. S. Rao and S. K. Srivastava, J. Phys. B 25, 2175 (1992)

FIG 5

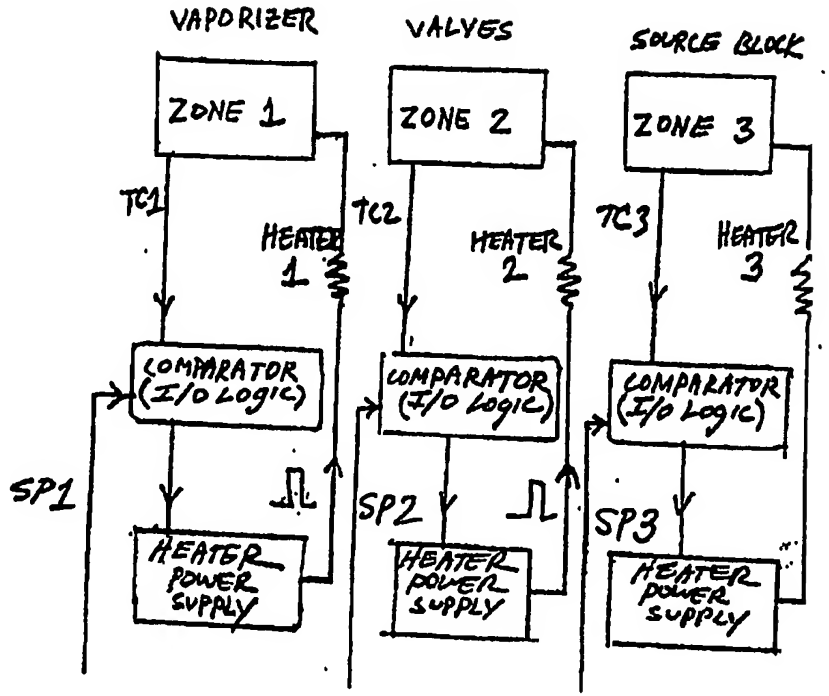


FIG 6 3-Zone Temperature Control System